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PARTIAL REFLECTION EXPERIMENT:
OPERATIONAL AND DATA REDUCTION TECHNIQUES

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By

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Under Contract DAA-76-D-0100

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S99QAXAD411 - Reaction Rates to Propagation
Work Unit 23 Variability of D-Region Ion Density and Conductivity

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Operational and analytical procedures for reducing D-region partial reflection data obtained at White Sands Missile Range (WSMR) were reviewed and analyzed with the expectation that this equipment would be used to deduce D-region electron density profiles during the total solar eclipse of 26 February 1979 in Canada. The procedures devised as the result of this study are applicable

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20. ABSTRACT (cont)

to data obtained during the eclipse at a Canadian site as well as to data obtained during longer term operation at WSMR.

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1.1 WSMR and the Partial Reflection Experiment

The WSMR is an ideal site for the partial reflection experiment. The site is remarkably free from interference; the lowest altitude for D-region backscatter is set by the sensitivity of the experimental equipment and by ground clutter and not by uncontrollable interfering signals. Measurements have shown that 24-hour round-the-clock D-region measurements are possible at this site.

The data reduction procedures in use at WSMR were inadequate on several counts. There was no screening procedure for saturated echoes. Furthermore, although the receiver is non-linear, correction for receiver non-linearity was made only after the A/D converter output had been averaged rather than correcting each receiver output sample and then averaging. Moreover, at high values of receiver attenuation, quantizing noise became important.

Finally, the method of data reduction was suspect. Although the Belrose and Burke (1964) formula was used, the collisional frequency profile was incorrect, the refractive index formula was not the best available and the data were reduced by logarithmically differencing measured values of A_x/A_o at 2-kilometer altitude intervals. The Physical Science Laboratory (NMSU) were aware of the errors associated with the differencing procedure and had suggested alternate methods of data reduction.

1.2 Data Screening and Reduction

The following suggestions were accepted by ASL and implemented as data screening procedures in the production of A_x/A_o profiles as a function of altitude.

1 - Each sampled output was corrected for receiver non-linearity before entering the averaging process.

2 - At each altitude and for each receiver attenuation setting, the number of samples with an uncorrected amplitude of less than 63 (the saturated A-D converter output) was made part of the computer print-out.

Before the data were further processed, additional screening procedures were instituted. Assuming that the amplitudes of both the O and X wave returns are Rayleigh distributed, one can calculate, as a function of true mean value of the echo, the percent of the samples which will exceed a count of 63 - the maximum output of a six-bit A-D converter. The results are presented in Table 1 below.

Table 1

Percent of samples exceeding 63 counts as a function of true mean value ($\bar{R}_{true}$)

$\bar{R}_{true}$	20	25	30	35	40	45	50
%>63	.04	.68	3.13	7.85	14.25	21.44	28.75
$\hat{\bar{R}}_1$	19.972	24.530	27.772	29.212	29.086	27.922	26.290
$\hat{\bar{R}}_2$	19.998	24.960	29.745	34.157	38.064	41.432	44.400

Also shown in Table 1 are the results of two different procedures for estimating the mean value. These last two entries will be discussed later. It is clear that if saturation is to affect less than 5% of the total number of measurements, mean values in excess of 32 linearized counts are to be eschewed. The WSMR receiver used 6 dB programmed gain steps and at altitudes where the mean value was greater than 30, the average of the next attenuation step (greater than 15 counts) was used.

An examination of experimental data indicated, not surprisingly, that mean linearized averages of less than 10 units suffered from appreciable quantizing errors; consequently, these data were not used. Good average values must be between 10 and 30 linearized A/D values with the additional constraint that the number of echoes used in the average ought to be greater than 95% of the total number of valid transmitted pulses.

The definition of a valid transmitted pulse was based on the fact that for the normal D-region above WSMR, appreciable echo amplitudes were not expected at altitudes as low as 50 km. If the echo amplitude at 50 km exceeded 5 or 10 units, the returns at all altitudes for that transmitted pulse were ruled invalid due to interference. The low interference levels at WSMR were reflected in the fact that A_x/A_o averages computed from valid pulse levels of 5 and then 10 units were virtually identical.

The final data screening procedures applied to the linearized A/D outputs were

1) The mean value had to lie between 10 and 30 counts.

2) The mean value had to be computed from at least 95% of valid transmitted pulses.

3) Individual amplitudes greater than 62 counts were discarded.

These screening criteria were complementary for the most part. Average amplitudes above 30 counts almost invariably had more than 5% of the echoes rejected for saturation. Average echo amplitudes less than 10 counts differed significantly from the averages in the next 6 dB gain column showing the effects of quantization noise. The screening procedures were readily implementable and produced consistent A_x/A_o profiles from the raw data. The A_x/A_o profiles so produced differed from similar profiles obtained by the author at Raleigh, North Carolina, in that the WSMR curves maximized at 78 kilometers whereas the Raleigh curves maximized between 70 and 72 kilometers. It was suggested that receiver delay was not properly accounted for in the WSMR data. Tests, conducted by PSL personnel, confirmed that this was the case and when receiver delay corrections were incorporated into the data reduction procedures, A_x/A_o profiles, similar to those obtained at Raleigh, resulted.

1.3 Alternate Means of Handling Data Reduction

In the data reduction process outlined above, all echoes whose instantaneous amplitude exceeded 62 were discarded and not used in the averaging process. This should result in a bias in the average $\hat{\bar{R}}_1$ to lower than true values. We propose to evaluate the magnitude of this bias. The third row in Table 1 indicates the estimate of the average $\hat{\bar{R}}_1$ as a function of the true average value $\bar{R}_{true}$. It can be seen that so long as less than 5% of the echoes exceed 62 (part of our screening procedure) the errors in estimating the true mean value are less than 7% — an acceptable value. However, Dr. Dave Mott of PSL suggested that we keep a count of the number of echoes which exceed 62 counts and, instead of discarding them, count them as 63. The estimate of the true mean value for this case is denoted by $\hat{\bar{R}}_2$ and is shown in the fourth row of Table 1. It is clear that so long as less than 15% of the echoes are saturated, this technique results in less bias in the estimate of the average over a wider range of true mean values. I recommend that this procedure be adopted in future data reduction procedures although I would recommend that apparent mean values greater than 35 be used with caution — the percentage of saturated echoes will be greater than 8 - 15% and possible combinations of sampling errors and saturated echoes may result in spurious results.

1.4 Deduction of Electron Density Profiles

The data screening procedures outlined in section 1.2 result in curves of A_x/A_o which must be further processed to produce electron density profiles. The experimental technique is based upon a theoretical prediction of the ratio of amplitude of the extraordinary return to the amplitude of the ordinary wave return. Theory predicts that the measured ratio as a function of altitude ought to behave as

$$\frac{\overline{|E_x|}^2}{\overline{|E_o|}^2} = \frac{|R_x(h)|^2}{\overline{|R_o(h)|}^2} \exp \{- \frac{8\pi}{\lambda} \int_0^h (n_x^i - n_o^i) \, dz\} \tag{1}$$

$\overline{|E_x|}^2$ is the mean squared amplitude of the X wave return.

$\overline{|E_x|}^2$ is the mean squared amplitude of the O wave return.

$\frac{|R_x|^2}{\overline{|R_o|}^2}$ is the ratio of the backscattering cross section (per unit volume) for X and O waves, respectively and is independent of electron density.

n_x^i is the imaginary part of the refractive index for the extraordinary wave.

n_o^i is the imaginary part of the refractive index for the ordinary wave.

$n_{o,x}^i$ are the absorption indices for the ordinary and extraordinary polarizations, respectively.

The ratio $\frac{\overline{|E_x(h)|}^2}{\overline{|E_x(h)|}^2}$ is proportional to the square of the ratio of the mean amplitude of the X wave (A_x) to the mean amplitude of the O wave (A_O) at that altitude and is a measured quantity. $\frac{\overline{|R_x(h)|}^2}{\overline{|R_o(h)|}^2}$ is a theoretical ratio. The difference between the measured and theoretical ratio is due to the differential absorption of the X and O wave polarizations and is a function of the electron density as a function of altitude.

The formula in equation (1) is essentially that used by Gardner and Pawsey (1954) in their original paper explicating the partial reflection technique. It is also the fundamental formula proposed by Belrose and Burke in their 1964 paper. Belrose and Burke were the first to use the Sen-Wyller formulation for the refractive index of an ionized, magnetized plasma - Gardner and Pawsey had used the older Appleton-Hartree formulation which assumed a constant mean free path independent of electron energy. Flood (1968) modified this basic formula to account for absorption within the scattering volume. In addition to this correction term, Flood proposed to invert equation (1) using a least squared fit to a polynomial solution for N(h), the electron density profile as a function of altitude, in place of solving a series of coupled difference equations for equation (1) evaluated at successive altitudes. The advantage of the least squared polynomial fit is that it minimizes the propagation of numerical and experimental errors in the inversion process associated with deducing electron density profiles from experimental data.

The major changes in the WSMR data reduction procedures instituted during this project were primarily the use of a least squared polynomial solution in place of the coupled difference equations previously used. Additional changes included a revised electron-neutral collisional frequency profile and a newer and more accurate approximation to the complete Sen-Wyller theory. These changes will be discussed in order.

A simplified collisional frequency profile suggested by Davis was used for data reduction (1969). At Raleigh we had been using a 3-piece fit to the 1962 COSPAR atmosphere and there were obvious differences between the two profiles. The Atmospheric Sciences Laboratory made available the results of 9 months of Robin Sphere data obtained at WSMR. [The Robin Sphere is a rocket launched sphere with an accurately known ballistic coefficient. Radar tracking of the sphere, released at rocket apogee, provides estimates of atmospheric density, pressure, and ultimately electron-neutral collisional frequency as a function of altitude.] The Robin Sphere data were analyzed and were found to agree very closely with the three-piece fit to the COSPAR atmosphere. This collisional frequency profile was therefore incorporated into the WSMR electron density reduction routine.

The Sen-Wyller formula for the refractive index of an ionized magnetized gas does not lend itself very well to computer inversion of equation (1) and solutions for electron density as a function of altitude. Belrose and Burke proposed a quasi-longitudinal (Q-L) approximation which was appropriate for the high geomagnetic latitude associated with their Ottowa location. Unfortunately, there was no way to logically extend their formation to lower latitudes. Flood (1974 unpublished) suggested the following Q-L approximation for D-region mid- as well as high-latitude refractive indices.

$$n_o = 1 - \frac{N(h)e^2}{2m\varepsilon_o\omega\nu(h)}\left[T_2(h) + j\ 5/2\ T_4(h)\right] \quad (2a)$$

$$n_x = 1 - \frac{N(h)e^2}{2m\varepsilon_o\omega\nu(h)}\left[T_1(h) + j\ 5/2\ T_3(h)\right] \quad (2b)$$

where $N(h)$ is the electron density at the altitude h

m = mass of an electron = 9.11×10^{-31} kg

e = charge of electron = 1.602×10^{-19} coulombs

ε_o = permittivity of free space = 8.85×10^{-12} farads/meter

$\nu(h)$ = electron neutral collisional frequency

ω = angular operating frequency (radians/sec)

$$T_1(h) = Ay_x\, C_{3/2}(y_x) + By_o\, C_{3/2}(y_o) + D\, C_{3/2}(y) \quad (3a)$$

$$T_2(h) = Ay_o\, C_{3/2}(y_o) + By_x\, C_{3/2}(y_x) + D\, C_{3/2}(y) \quad (3b)$$

$$T_3(h) = A\, C_{5/2}(y_x) + B\, C_{5/2}(y_o) + D\, C_{5/2}(y) \quad (3c)$$

$$T_4(h) = A\, C_{5/2}(y_o) + B\, C_{5/2}(y_x) + D\, C_{5/2}(y) \quad (3d)$$

$$A = \cos^2(\phi/2) - \frac{1}{4}\sin^2(\phi/2) \quad (4a)$$

$$B = \sin^2(\phi/2) - \frac{1}{4}\sin^2(\phi/2) \quad (4b)$$

$$D = \frac{1}{2}\sin^2(\phi) \quad (4c)$$

ϕ = acute angle between the direction of propagation and the earth's magnetic field (4d)

$$y_x = \frac{\omega-\omega_H}{\nu(h)} \quad ; \quad y_o = \frac{\omega+\omega_H}{\nu(h)} \quad ; \quad y = \frac{\omega}{\nu(h)} \quad (4e)$$

ω_H = angular electron gyrofrequency = $\frac{eB}{m}$

B = magnetic flux density of earth's field (webers/m^2=Teslas)

$$C_p(y) = \text{semi-conductor integral} = \frac{1}{p!}\int_0^\infty \frac{x^p e^{-x}}{x^2+y^2}\, dx \quad (4f)$$

The polynomial approximations to the semiconductor integral (O'Hara 1964) can be used profitably in the data reduction process.

It now remains to evaluate the ratio of backscattering cross-sections for the extraordinary to ordinary polarizations. In terms of equation (1)

$$\frac{|R_x(h)|^2}{|R_o(h)|^2} = R^2(h) = \frac{T_1^2(h) + \frac{25}{4} T_3^2(h)}{T_2^2(h) + \frac{25}{4} T_4^2(h)} \tag{5}$$

Flood's 1968 correction would multiply $R^2(h)$ by:

$$\frac{n_o^i(h)}{n_x^i(h)} \quad \frac{\sinh(\frac{2\pi}{\lambda} n_x^i c\tau)}{\sinh(\frac{2\pi}{\lambda} n_o^i c\tau)}$$

where τ is the resolvable system pulse length.

If the pulse length τ is short enough (less than 25 microseconds) and the electron densities not too high, Flood's correction term does not differ significantly from unity. In instances of unusually high absorption, this correction term may be important even for pulse lengths as short as 20-25 microseconds. Note that the effective pulse length of the system is determined by the entire receiver response and not just by the transmitted pulse length. The effective pulse length is given by the convolution of the impulse response of the receiver (a measurable quantity) and the transmitted pulse shape (also measurable). The overall response of the receiver can be measured by noting the 3 dB width of the returned pulse from a classical E-region return wherein echoes are found only over a narrow range of altitudes. At any rate, it appeared that for the normal daytime D-region above WSMR, the Flood correction is not necessary over the altitude region 60-90 kilometers, using 20 microsecond effective pulse lengths. The current procedure in use at WSMR neglects Flood's correction term. The form of equation (1) in use at WSMR is therefore given by

$$\left(\frac{\bar{A}_x(h)}{\bar{A}_o(h)}\right)^2 = \frac{T_1^2(h)+\frac{25}{4}\,T_3^2(h)}{T_2^2(h)+\frac{25}{4}\,T_4^2(h)} \quad \exp\left\{-\frac{8\pi}{\lambda}\int_0^h (n_x^i - n_o^i)\,dz\right\} \quad \ldots(7)$$

where all symbols have been defined in equations 2,3, 4,5 and 6.

$\left(\frac{\bar{A}_x}{\bar{A}_o}\right)^2$ is known from measurements at 2-kilometer altitude increments. T_1, T_2, T_3, T_4 are known functions of altitude, electron gyrofrequency, operational frequency and magnetic dip angle. The differential absorption term, $\exp\{-\frac{8\pi}{\lambda}\int_0^h (n_x^i - n_o^i)\,dz\}$, is the only term involving electron density.

There are two ways of inverting (7). The first, used by Gardner and Pawsey (1953) and Belrose and Burke (1964), is to take the logarithm of equation (7) and then obtain a series of coupled difference equations which can be solved for a slab-wise approximation to the electron density at each height h. Flood, in 1968, suggested use of a polynomial solution for electron density to provide a least squared fit to the logarithm of $(\frac{\bar{A}_x}{\bar{A}_o})^2$. The least squared fitting procedure can be applied to equation (7) whether Flood's correction term is used or not. Furthermore, one has the option of weighting the contributions to the mean squared residuals. In particular, Flood (1968) suggested minimizing the mean squared percentage error. The current WSMR procedure uses a polynomial approximation for the electron density profile with uniform weighting of the mean square errors. The advantage of the polynomial solution is that each measured point is recognized for what it is — an estimate of the true value of $(\frac{\bar{A}_x}{\bar{A}_o})^2$ at that altitude rather than forcing a solution to pass through every experimental point — some of which may be significantly in error. The coupled difference equation solution suggested by Gardner and Pausey is very prone to numerical instability. A slight error at a low altitude leads to large errors (negative electron densities) at higher altitudes. The polynomial least squared fit, when the order of the polynomial is restricted to less than half the number of heights at which $\frac{\bar{A}_x}{\bar{A}_o}$ is determined, does not suffer from this problem.

1.5 Operation at an Additional Frequency at WSMR

The equipment installed at WSMR consists of two separate transmitters capable of 200 kw peak pulse power outputs, two receivers and sufficient digital data recording apparatus to enable partial reflection operation at two different frequencies. The advantage of such an arrangement is that a lower frequency (say, 2.66 MHz) can be used to deduce electron densities over the range, say, of 60 - 88 kilometers and a higher frequency can be used to explore electron densities over the range (say) of 75 - 95 kilometers. Candidate frequencies for the second system were 4.5 and 6.0 MHz.

Calculations of the expected $\frac{\bar{A}_x}{\bar{A}_o}$ ratio expected at 4.5 and 6.0 MHz operation at WSMR using average summer and winter D-region electron density profiles (as experienced in Raleigh, NC) were made and the results presented in Figures 1 and 2. It is apparent that if meaningful data are to be collected on a diurnal basis, the second operating frequency should be between 2.66 and 4.5 MHz.

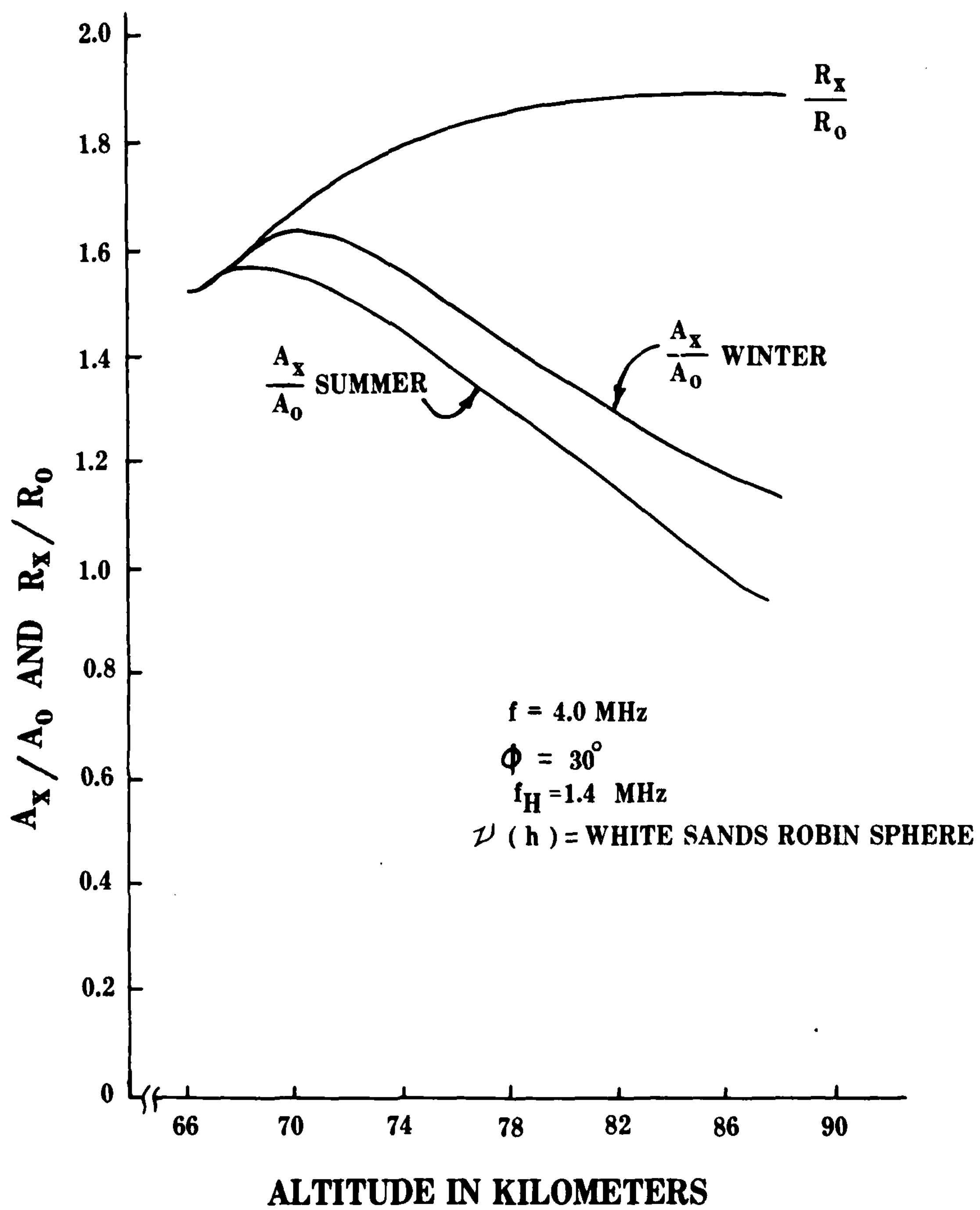

Figure 1. Calculated ratios of A_x/A_o and R_x/R_o.

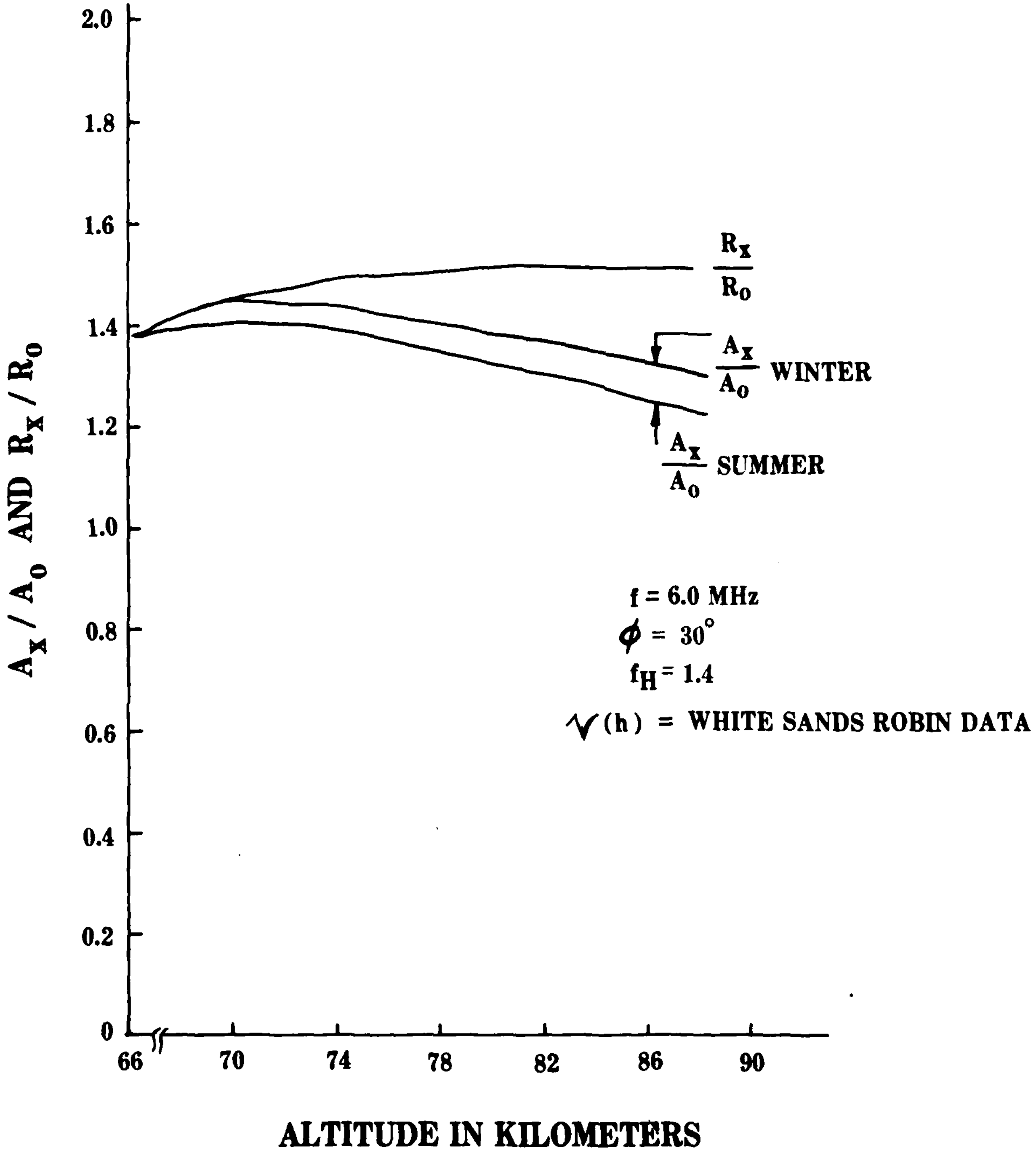

Figure 2. Calculated ratios of A_x/A_o and R_x/R_o.

WSMR Conclusions and Recommendations

The data screening procedures described above can minimize the task of deducing valid electron density profiles from the raw data. There is one additional constraint to the overall data reduction problem which needs to be addressed: the order of the polynomial in electron density used to describe the $(\frac{A_x}{A_o})^2$ data points. It is clear that in the D-region, the electron density increases very roughly, exponentially with altitude. We require at least seven valid contiguous measurements of $(\frac{A_x}{A_o})^2$ as a function of altitude for the data run to be considered for further analysis. If there are at least seven valid contiguous altitude measurements of $\frac{A_x}{A_o}$, the order of the polynomial for electron density is constrained to be less than $(n-1)/2$ where n is the number of contiguous $\frac{A_x}{A_o}$ measurements. Although the constraints enumerated above may reject a large quantity of data collected at a normal D-region station, WSMR, because of its isolation, can in fact collect a large quantity of valid data.

If WSMR institutes a second operational frequency, then a frequency of approximately 3.5 MHz is strongly recommended. At WSMR, these two frequencies should be able to provide reasonable noon-time electron density profiles over the region 66 to 94 kilometers. Furthermore, substantially more valid data could be procured if an eight-bit A/D converter were substituted for the six-bit converter currently in use. It is recommended that future programs at WSMR utilize a gain-programmable, "super-linear" receiver of the type in use at Raleigh. The major portions of a gain-programmable, "super-linear" receiver have been delivered to PSL.

Part II - Eclipse Measurements

2.1 The Physical Sciences Laboratory, New Mexico State University, was to operate the partial reflection experiment in Canada during the total solar eclipse of February 26, 1979. In anticipation of problems which might be encountered in reducing partial reflection data from the eclipse site, equipment calibration and data reduction procedures in use at the WSMR field site were reviewed and the results of this review have been presented as Part I of this report.

It was not expected that the P.R. experiment would provide ground-based observations of the rapid changes in electron density at altitudes between 65 and 80 kilometers as a result of the obscuration of the sun during the eclipse. The P.R. experiment was expected to provide continuous (as contrasted to the instantaneous rocket measurements) measurements of electron density above 80 kilometers and continuous, "filtered" measurements of electron density below 80 kilometers. Furthermore, although a few rockets can be fired on "control" days to ascertain normal variations of electron densities in the D-region, the P.R. experiment offered the opportunity to continuously measure D-region electron densities at almost all times after the equipment has been installed.

The D-region results from the Eclipse Experiment, while not unexpected because of the high geomagnetic latitude of the experiment site, were significantly different from those results expected from an eclipse experiment at a mid- or low-latitude site. These differences cause some difficulty in data analysis. An example of the kind of difficulty can be seen from an inspection of Table 2.

Table 2 lists the average value of the A-D output (after linearization) for ordinary and extraordinary returns as a function of apparent altitude. This is a 1-minute sample taken at 1044, February 26, 1979 — approximately 9 minutes before second contact. One hundred pulses for each polarization and each attenuation were used to compute the averages. An asterisk in the corner of each listing indicates that more than 5% of the echo amplitudes were saturated (count = 63 units). These values were not used in the calculation of the $\frac{A_x}{A_o}$ ratios.

If we restrict our analysis to those altitudes at which less than 5% of the echoes were saturated and in which the mean values were between 10 and 30 units, then we can see that the 6 dB incremental receiver gain change is reflected in the data. For example, using ordinary wave polarization, the first altitude at which the echo amplitude at both 6 dB and 12 dB attenuation levels are both within the range 10 - 30 linearized counts is a 66 km. The average amplitude at the 6 dB attenuation level is 23.128 counts. The corresponding average amplitude for the 12 dB attenuation level is 11.571 counts — differing by only .06% from the expected value of 11.564. Furthermore, look at the A_o values in the 12 and 18 dB attenuation level columns.

TABLE 2. CORRECTED MEAN RECFIVER OUTPUT AS A FUNCTION OF ALTITUDE POLARIZATION AND ATTENUATION SETTING

	A_o				A_x				
	0	6	12	18	0	6	12	18	A_x/A_o
50	31.611	16.724	7.690	2.557	24.764	12.457	4.614	.414	.761
52	27.977	15.482	7.099	1.444	28.404	14.009	5.461	.482	.957
54	34.523*	19.236	9.418	2.177	27.477	15.700	7.226	1.693	.765
56	27.307*	16.196	6.533	1.303	20.910	11.256	4.161	1.227	.670
58	23.384*	10.403	3.631	.815	20.955	10.850	3.133	.424	1.025
60	26.952*	12.943	5.346	1.337	26.513	13.630	4.956	.723	1.039
62	28.037*	14.377	6.453	1.900	28.922	16.466	6.448	1.387	1.076
64	30.822*	17.357	9.207	2.619	36.043*	22.756	11.489	3.777	1.317
66	34.509*	23.128	11.571	4.085	35.493*	27.793	14.640	6.215	1.253
68	38.329*	25.598	13.196	5.080	38.906*	28.870	14.097	6.555	1.098
70	34.788*	25.172	11.985	4.584	32.723*	23.162	11.293	3.903	.951
72	37.742*	24.490	10.814	4.493	30.581*	16.880	7.409	1.816	.732
74	46.874*	38.178*	27.671	13.919	29.619	14.196	6.438	1.402	.261
76	50.488*	43.318*	34.518*	24.478	30.174*	17.807	8.414	2.867	.182
78	52.522*	40.309*	32.431*	22.451	30.034*	15.718	7.878	2.126	.175
80	42.711*	36.781*	24.976	13.412	25.847	13.786	5.175	.820	.258
82	34.398*	23.058	12.369	5.243	23.681	11.900	3.625	.673	.497
84	28.121*	13.975	6.768	1.375	18.794	10.565	2.514	.273	.714
86	31.570*	18.251	8.296	2.775	18.181	8.405	3.187	.705	.498
88	32.874*	20.391	8.789	3.044	18.878	8.225	2.957	.224	.465
90	32.761*	18.998	8.675	2.266	20.581	8.383	3.123	.872	.542
92	26.565*	14.207	6.903	1.455	19.138	8.719	3.026	.833	.674
94	21.696	13.470	4.403	.723	20.022	8.514	2.577	.866	.823
96	21.192	11.928	4.479	.970	21.149	10.549	2.989	.664	.938
98	19.204	11.118	4.025	.615	18.789	10.384	1.570	.705	.955
100	20.355	9.614	3.405	.614	18.955	8.169	2.542	.333	.931

If the count in the 18 dB column is less than 10, it is very difficult to see a factor of 2 (6 dB difference) in the two column values; note, however, that at 74 and 80 kilometers where both counts are within the 10-30 count range, the significance of the 6 dB (factor of 2) gain change is clearly shown. The 6 dB and 12 dB columns illustrate even more clearly that if both values lie between 10 and 30 counts, it is only sampling error which disturbs the factor of 2 expected difference. We take these observations as further evidence of the desirability of confining the valid entries to those values which lie between 10 and 30 counts (all data having less than 5% saturated values).

The $\frac{A_x}{A_o}$ ratioswere computed only for those entries which met the screening criteria above. When values were available for two attenuation levels — such as 56 km for the ordinary wave in Table 2 — the two values were averaged (giving a 6 dB value of 23.135 for example in Table 2, 66 km).

In looking over the eclipse data furnished by ASL, the author noted that at no altitudes (using say 6 dB ordinary wave values in Table 2) did the tabulated values go significantly below a count of 10 units. One might be tempted to say that for this gain setting something like a count of 10 constitutes a "noise" level such that all 6 dB values listed ought to have a count of 10 subtracted in order to account for the "noise" contribution. [For the 12 dB column, the least value listed is approximately 3.5

and 3.5 might be considered the "noise" contribution to the 12 dB values.] One can construct new $\frac{A_x}{A_o}$ profiles corrected for noise in this fashion and this author has done so - - even though at Raleigh we never used a "noise" correction. Upon reflection, at least for the eclipse data, such a correction is not warranted. In fact, after making such "noise" corrections, the factor of 2 between successive 6, 12, 18 dB columns disappears at essentially all altitudes. The preliminary electron density profiles using a noise correction produced by this author in meetings with ASL personnel, cannot be supported and should be ignored.

It is clear that 1-minute averages of echo amplitudes suffer from sampling errors but that longer averaging times will prevent the recognition of any rapid eclipse-produced changes in electron density. Consequently, it is recommended that 1-minute averages of $\frac{A_x}{A_o}$ produced by the screening procedures already discussed (less than 5% saturation and counts between 10 and 30) should in turn be averaged with a running weighted average: a 3-minute average with a 1,2,1 weighting readily suggests itself. These weighted $\frac{A_x}{A_o}$ averages should then be subjected to a polynomial inversion and in view of the high absorption experienced at the eclipse site, the inclusion of the "Flood sinh term" is recommended. The polynomial solution can then be weighted to minimize the percentage error in the $\frac{A_x}{A_o}$ profile.

The profile of $\frac{A_x}{A_o}$ available from Table 2 is interesting (and in some ways inexplicable) from several points of view. At a normal mid-latitude station one expects the $\frac{A_x}{A_o}$ profile to increase monotonically to a maximum value and thereafter decrease. Below 56 kilometers and above 78 kilometers this expected behavior is not reflected in the experimental data. Measurements of the cone angle of arrival of D-region echoes at Raleigh, NC, show that when this expected pattern is not followed, oblique echoes and altitude smearing are frequently encountered. Provision to measure the cone angle of arrival of the D-region echoes was not available at the eclipse site so that the cause of the inexplicable behavior of the $\frac{A_x}{A_o}$ ratio above 78 kilometers cannot be documented at this time. I would not include experimental values outside the 58-to 78-kilometer region were I reducing the data shown in Table 2. Unless there were extraordinarily strong effects for the differential absorption within the scattering volume — Flood's correction — it is difficult to explain the non-monotonic behavior of the $\frac{A_x}{A_o}$ profile above 78 kilometers and blind data reduction which attempted to produce electron density profiles from these data would be thoroughly suspect.

In summary, the data from the eclipse of 2/26/79, taken from a site in Canada, show strong particle ionization characteristics — so strong that the solar eclipse may have had only a minor effect upon the D-region electron densities during the course of the eclipse. The "control day" data for the most part also show strong particle ionization effects.

While the P.R. data gathered during the eclipse expedition may not have fulfilled the expectations of a solar controlled experiment, the P.R. data, backed up by a most unique array of in-situ rocket measurements, can very well provide the best documented and measured example of a particle precipitation event yet extant. The eclipse experiments include rocket borne measurements of all kinds of input flux to the D-region, P.R. electron density profiles, rocket borne measurements of electron density and rocket borne mass spectrometry measurements of positive and negative ion density.

In many ways the eclipse data may be more definitive in checking the DAIRCHEM code's predictions than the morphology of a classical solar eclipse might have been. The data collected during the eclipse expedition are appropriate to a particle ionized D-region — something closer to the real requirement for a DAIRCHEM code check than could be provided by a simple solar eclipse.

Part III - Summary and Conclusions

A quick look at the eclipse P.R. data implies that the eclipsed D-region was dominated by exceptionally strong particle ionization sources. Even pre-eclipse and post-eclipse runs frequently show non-solar controlled $\frac{\bar{A}_x}{\bar{A}_o}$ profiles. The P.R. results coupled with the rocket-borne in-situ measurements of the eclipse experiment in Canada can very well provide more interesting scientific data and better tests of the DAIRCHEM code predictions than could a conventional lower latitude eclipse experiment.

It is recommended, in view of the high absorption, that the Flood "sinh" correction term be incorporated into the analysis. It is also recommended that no "noise" correction be made to the data. Finally, following the suggestion of Dave Mott to include saturated data points (at a 63 value) provided less than, say, 15% of the samples at that altitude are saturated is endorsed. The interference situation at the experimental site in Canada was such that the imposition of valid data screening levels at 50 kilometers seems not necessary, and misleading in that there were real D-region echoes at 50 kilometers.

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